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Souris River Automatic Water Quality Monitoring

1977 - 1982

Report 2: Evaluation of the Automatic Monitors

June 1984

SOURIS RIVER AUTOMATIC WATER QUALITY MONITORING
1977 to 1982

Report 2: Evaluation of the Automatic Monitors

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PREFACE

The Water Quality Branch, Environment Canada, operated automatic water quality monitors at two location on the Souris River during the period 1977 to 1982, for the purpose of providing continuous water quality data for four physical variables.

The results of the study are presented in two reports:

Report 1: Preliminary Data Interpretation presents and discusses the water quality data gathered during the study period.

Report 2: Evaluation of the Automative Monitors provides a discussion of the use of automatic monitoring for the collection of baseline data.

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1.0 INTRODUCTION

The Water Quality Branch, Environment Canada, initiated automatic water quality monitoring (auto-monitoring) at two locations on the Souris River in 1977 and 1978. The program consisted of continuous automatic monitoring for physical variables supplemented by monthly grab samples for a broad spectrum of water quality variables. The automatic monitoring portion of the program was discontinued in June 1982.

The major objective of the program was to provide continous water quality data for use as a baseline against which potential effects of the Garrison Diversion Unit Project (GDUP) could be assessed and/or predicted. A second objective was to evaluate the use of automated equipment as a monitoring tool. This paper addresses the second objective, providing a discussion of operational benefits and difficulties, costs, and data accuracy. The data collected during the period 1977-1982, together with an evaluation of their adequacy in meeting the major objective, are presented in Report 1: Preliminary Data Evaluation.

2.0 METHODS

Two monitoring locations were established on the Souris River (Figure 1) near the International Boundary, above and below the Souris Loop, the United States portion of the river. The upstream station was situated near Glen Ewen, Saskatchewan (Lat. 49°11' 02" N Long. 102° 01' 42" W), and the downstream station near Coulter, Manitoba (Lat. 49°

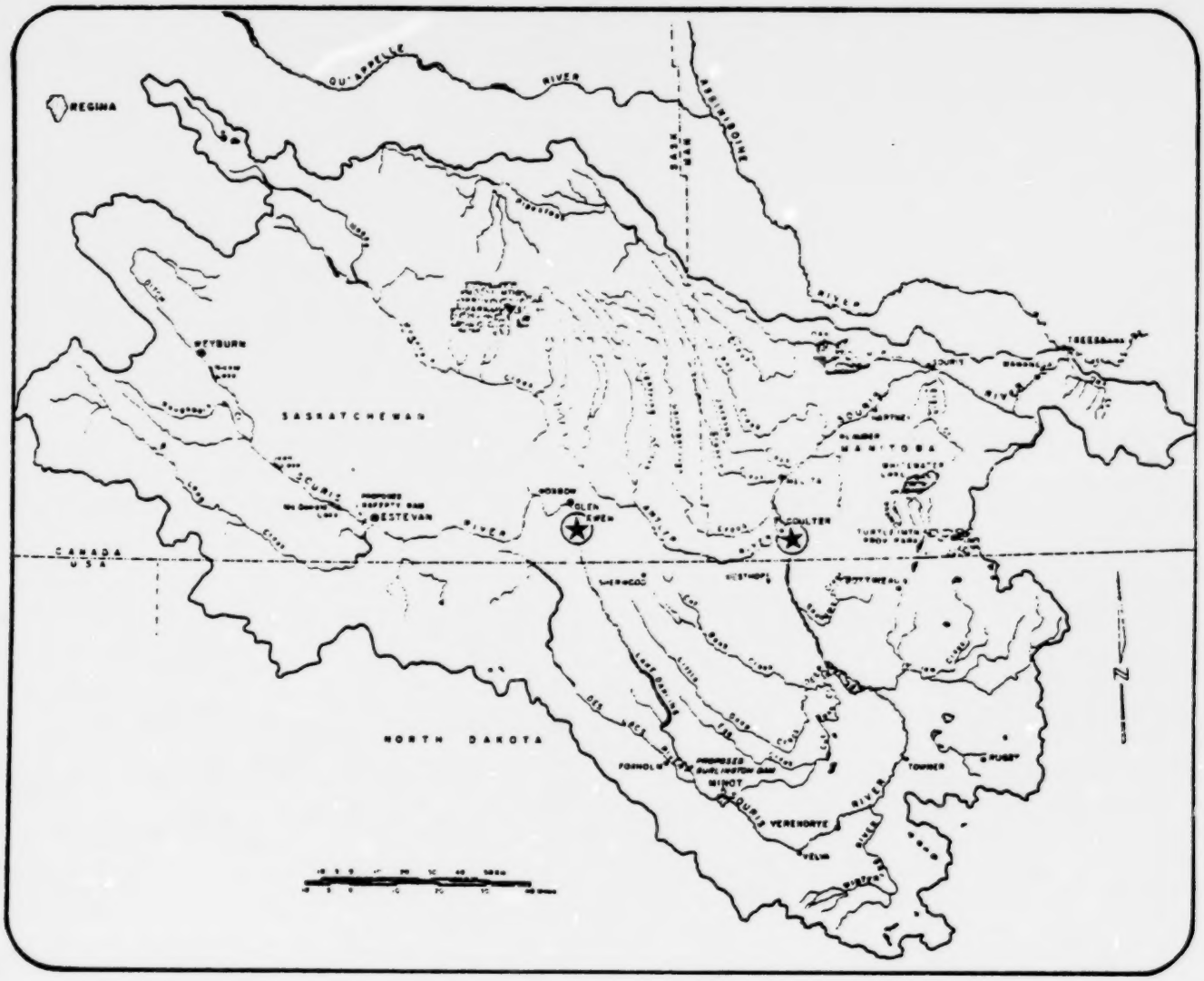

Figure 1. Souris River Automatic Monitor Sites

05' 27" N Long. 100°57' 12" W). The stations were co-located with hydrometric gauging stations operated by Water Survey of Canada (station numbers 05ND001 and 05NF016, respectively). The monitors were installed on August 11, 1977 at Glen Ewen and April 7, 1978 at Coulter.

Philips automatic water monitors (model PW9835) were installed to provide continuous monitoring of four physical variables: water temperature, pH, dissolved oxygen, and conductivity. Employing a continuous flow-through probe block and self-standardization, the Philips monitors were designed to provide continuous recording of up to six variables with minimum maintenance.

The monitors were located in insulated steel shelters fitted with heaters and air conditioners to maintain the inside air temperature between 15° and 25° degrees C throughout the year. At the Glen Ewen site, the monitor was situated on the river bank approximately 15 meters from the normal shoreline and four meters above the water surface. During most of the study, the intake orifice was located near mid-stream. The intake line was housed in an underground steel pipe leading to a well located on the shoreline. From the well to the monitor shelter, the heat traced intake line passed through an insulated utilidor. The total distance from the intake orifice to the monitor was approximately 25 meters. On occasion fouling of the intake lines necessitated backflushing and the use of submersible pumps and surface intake lines.

The Coulter monitor was located on an abandoned highway bridge approximately five meters above the normal water level. The intake was housed in a steel culvert which was suspended below the monitor shelter

directly into the river.

In 1979, the monitors were fitted with data collection platforms (DCP's) to provide automatic transmission of results, and to allow immediate viewing of the monitors' performance. The monitoring system is illustrated in Figure 2.

Data from the monitors were retrieved daily from a satellite receiving station in Maryland and stored in the Water Quality Branch computer located in Regina. Monthly monitor reports were prepared for each station, including daily and monthly means for each variable. Prior to the preparation of the monthly monitor reports, manual editing of the data was necessary to remove obvious errors resulting from monitor or transmission-related problems. While this editing process was by necessity subjective, an attempt was made to reject only those data known to be in error due to specific and understood causes.

Scheduled monthly maintenance was performed at each monitor. This included cleaning and general trouble-shooting of all equipment including pumps, lines, monitors, and DCP's, and calibration of the monitor's output. In addition, nonscheduled maintenance was performed when data transmissions indicated malfunction.

Problems with the self-standardization systems became obvious shortly after the monitors were installed. Mechanical slides located within the monitor block, used to isolate the measurement probes within separate chambers for the daily standardization process, were found to be prone to sticking due to fouling with suspended matter. After several months of operation, the slides began to wear, allowing standard solutions to leak into the monitor blocks. It was necessary

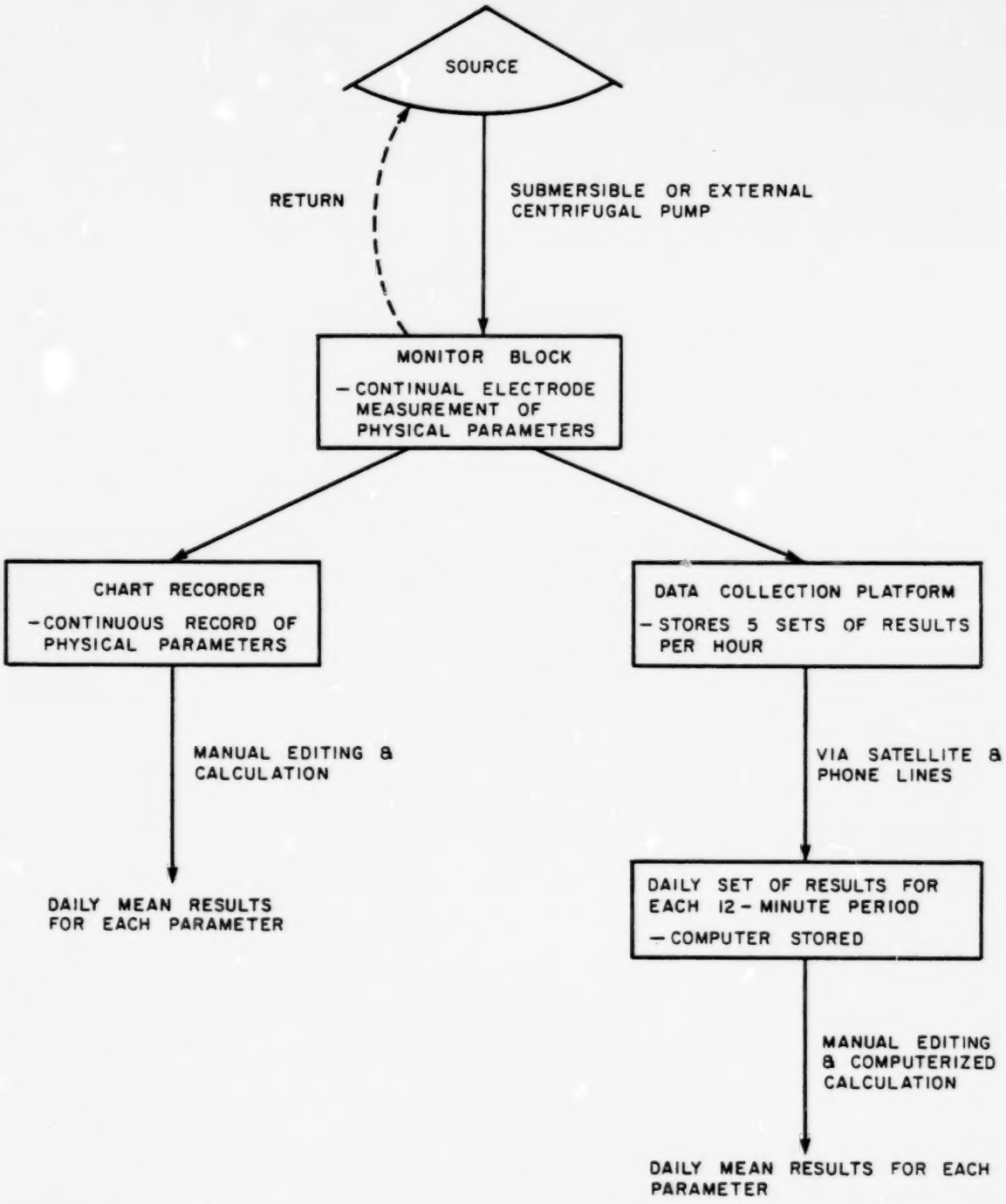
SOURCE
RETURN
SUBMERSIBLE OR EXTERNAL CENTRIFUGAL PUMP
MONITOR BLOCK
- CONTINUAL ELECTRODE MEASUREMENT OF PHYSICAL PARAMETERS
CHART RECORDER
- CONTINUOUS RECORD OF PHYSICAL PARAMETERS
DATA COLLECTION PLATFORM
- STORES 5 SETS OF RESULTS PER HOUR
MANUAL EDITING & CALCULATION
VIA SATELLITE & PHONE LINES
DAILY MEAN RESULTS FOR EACH PARAMETER
DAILY SET OF RESULTS FOR EACH 12 - MINUTE PERIOD
- COMPUTER STORED
MANUAL EDITING & COMPUTERIZED CALCULATION
DAILY MEAN RESULTS FOR EACH PARAMETER

Figure 2. Schematic of the Data Collection Procedure using Automatic Monitors.

thereafter to rely on manual calibration which was performed during scheduled and nonscheduled maintenance trips, an average of three times per month.

Prior to the breakdown of the automatic daily standardization process, manual shift corrections were applied to the data to correct for probe drift. It was felt that this drift could be assumed to be linear over a 24 hour period, and simple interpolation was applied. Subsequent to the loss of automatic daily standardization, it was not possible to assume linear drift due to the greatly decreased frequency of manual calibration. Therefore, from 1979 onwards, shift corrections were not applied, reducing confidence in the accuracy of the data.

In addition to the auto-monitoring portion of the program, monthly hand collected samples were taken at each monitoring site to provide information on a broad range of water quality variables, and to allow comparisons with auto-monitoring results.

3.0 RESULTS AND DISCUSSION

3.1 OPERATIONAL RECORD

The operational periods of the two monitors are summarized in Table 1. The distinction between "installation period with flow" and "operational period" reflects shutdowns during winter when monitor operation often proved impractical. The data records for the four water quality variables are, on average, 44.2 per cent complete for the

Table 1. Summary of the Automatic Monitoring Record

Site	Installation Period (Days)	Installation Period with Flow (Days)	Winter Shutdown Period (Days)	Operational Period (Days)	Variable	Days of Record	% Record Operational Period	% Record for Installation Period with Flow
Glen Ewen	1785	1701	626	1175	Sp Conductance	803	68 3	47 2
	11/8/1977 to 30/6/1982				pH	737	62 7	43 3
					Dissolved Oxygen	684	58 2	40 2
					Temperature	786	66 9	46 2
					Mean	752	64 0	44 2
Coulter	1545	1412	101	1311	Sp Conductance	791	60 3	56 0
	7/4/1978 to 30/6/1982				pH	727	55 5	51 5
					Dissolved Oxygen	652	49 7	46 2
					Temperature	856	65 3	60 6
					Mean	757	57 7	53 6

Notes: Days of record are the number of days for which at least 12 hours of data are available for the calculation of daily means

The percent of operstional period is the percentage of data available relative to the period for which the monitor was operated.

The percent record for the period of installation with flow is the percentage of data available relative to the number of days during the installation period which had measureable flow

Glen Ewen site, and 53.6 per cent complete for the Coulter site (Table 1). Loss of data was attributed to two major causes: winter shutdown and equipment breakdown.

Winter shutdown resulted in the loss of 31 per cent and 7 per cent of the potenial data bases at Glen Ewen and Coulter, respectively. It was necessary to shut down the Glen Ewen monitor for varying lengths of time each winter during low flow periods, due to repeated freezing of intake lines caused by breakdown of pumps and plugging of the intake orifice. Once frozen, the intake lines were extremely difficult to clear. Winter operation at Coulter was facilitated by the physical advantage of short and well protected intake lines . The Coulter monitor operated throughout the winters of 1978-79 and 1980-81.

The continuity of the operational periods for each variable at the two locations is shown graphically in Figure 3. The duration of the annual winter shutdowns at Glen Ewen varied from approximately six weeks in the winter of 1979-1980 to nearly six months in the winter of 1980-81. The average length of shutdown was four months, corresponding roughly to the period December-March inclusive. As a result, the Glen Ewen data base does not adequately characterize conditions during the winter period. The data record from the Coulter site is more representative of year-round conditions, with only two winter shutdowns being necessary. Periods of no flow necessitated shut down of the monitor at Coulter during the winters of 1979-80 and 1981-82, and at Glen Ewen during the late summer and fall of 1981.

Figure 3. Continuity of the Monitoring Records.

Equipment malfunctions were responsible for losses of an additional 25 and 40 per cent of the potenial data at Glen Ewen and Coulter, repectively. Figure 3 shows that the frequency and duration of breakdown decreased somewhat in the later years of operation. This was largely due to the installation of DCP's which allowed viewing of the monitors' output on a daily basis. Increased experience on the part of maintenance personnel may also have contributed to this improved performance.

3.2 OPERATIONAL DIFFICULTIES

Equipment failures, as noted earlier, were responsible for losses of 25 per cent and 40 per cent of the potential data at Glen Ewen and Coulter, respectively. Three major types of failure occurred.

i) Monitor Malfunctions

The automatic standardization system proved to be inoperable after the first year of operation due to frequent jamming and eventual wearing of the standardization slides. Slide wearing was caused by sediment scoring, essentially due to an inadequate design for waters of the type being monitored. A considerable amount of data was lost during the first year of operation as a result. Following removal of the automatic standardization system, it was necessary to rely on manual calibrations which were done at time of visit. The degree of confidence in the accuracy of the data base was impaired by this

reduction in the frequency of standardization and calibration.

Probe malfunctions occurred on numerous occasions. Probe fouling caused by algae and other suspended matter, as well as probe design faults (notably with respect to the dissolved oxygen probes) and problems with module electronics, were the most frequent causes of these malfunctions. The pH and dissolved oxygen probes were most susceptible to failure.

The chart drive mechanisms, paper guides, print heads, and drive motors were also prone to breakdown. These resulted in significant data loss in the first 18 months of operation, during which time the charts were the only form of data storage.

Other monitor malfunctions were attributed to blown fuses, faulty wiring, and leaks in blocks and standardization lines. Overall, breakdown of various monitor parts were responsible for about half of the total equipment-related data loss.

ii) Pump and Plumbing Malfunctions

Failures in pumps and plumbing components occurred on a number of occasions. A variety of centrifugal and submersible pumps were used over the study period with varying degrees of success. The most durable pumps were found to be Prosser submersibles, which could generally be relied on to perform continuously and service free for six months to a year.

Rapid increase in flow during the spring period, coincident with floating debris and ice, dislodged pumps and plugged intakes on a number of occasions. This problem was most prevalent at the Glen Ewen site.

iii) Data Transmission

A small amount of data loss was attributable to data transmission problems caused by loss of DCP power, faulty antennae aiming, and problems with the interface units between monitors and DCP's.

3.3 ACCURACY OF THE AUTO-MONITORING DATA

Monthly grab samples were collected at each monitor site to provide coverage of a broad range of variables and to provide a corroborative data set (Tables 2 and 3) for use in estimating the accuracy of the auto-monitoring results. Correlation of the monthly grab measurements with the corresponding instantaneous monitor results are presented in Figures 4 and 5. The degree of correlation between the two data sets can be considered to be a measure of the degree of accuracy of the auto-monitoring data.

Good correlation existed between grab and monitor results at Glen Ewen and Coulter for conductivity (r^2=0.91, 0.92 respectively) and water temperature (r^2=0.96, 0.98 respectively). Results for pH and dissolved oxygen were found to be poorly correlated, with coefficents

Table 2. Monthly Grab Sample Data Versus Corresponding Instantaneous Monitor Data at Coulter, 1978 to 1982.

Date	Temperature (deg C)		Sp. Conductance (us/cm)		pH (pH units)		Dissolved Oxygen (mg/L)	
	Grab	Monitor	Grab	Monitor	Grab	Monitor	Grab	Monitor
6/4/78	0.0		2000.		7.2	7.7		
8/6/78	9.0		760.	760.	7.3	8.0	9.4	4.2
20/9/78	7.5		1020.		8.5	8.2	8.5	5.8
17/10/78	4.0	4.0	1060.	800.	8.7	8.3	10.5	6.3
28/11/78	0.0	0.0	1240.		8.2	8.4	9.7	3.4
27/3/79	1.5	0.5	1580.	1280.	7.5			
16/4/79	9.5	10.8	560.	480.	8.4	8.5		
15/8/79	14.0	15.3	825.	800.	8.6			
25/9/79	15.5	17.5	900.	800.	8.5	9.0		
19/11/79	1.0	3.3	1170.	940.	8.0	8.5	13.5	11.4
12/2/80	0.0	0.0	2300.	1840.	7.3	7.5	1.2	1.2
24/4/80	8.5	12.3	540.		7.6	8.2	10.2	7.8
26/6/80	15.5	16.6	930.	828.	8.9	10.0		
22/7/80	20.0	21.4	1000.	1039.	8.4		4.4	5.0
13/8/80	18.0	19.1	1000.	914.	7.6		3.4	3.3
28/10/80	0.0	1.5	1250.	1031.	8.6	8.5	12.1	11.6
9/12/80	0.0	0.0	1600.	1633.	8.0	8.0	11.3	11.9
23/1/81	0.0	1.9	2200.	1719.	7.5	7.2	3.0	2.2
17/2/81	0.0	1.3	2000.	1859.	7.6	7.4	5.1	2.1
17/3/81	0.0	2.9	1000.	937.	7.8	7.8	11.7	9.5
7/4/81	4.0	6.9	550.	539.	8.3	8.2		
21/5/81	16.0	17.6	800.	765.	8.5	8.1		
25/6/81	17.0	18.0	900.	937.	8.7	8.7	10.1	8.7
28/7/81	18.0	19.0	1000.	1031.	8.5	8.4	5.5	4.3
22/9/81	11.0	12.5	960.	906.	8.8	8.8	8.4	5.5
17/11/81	0.0	2.0	1080.	1070.	8.8	8.6	12.8	13.4
12/8/81	0.0	2.0	1350.	1367.	8.2	8.5	6.4	11.4
26/5/82	19.0	21.6	650.	781.	8.1	8.6	7.8	8.3
6/2/82	14.0	16.9	770.	859.	8.2	8.7	8.3	4.6

Table 3. Monthly Grab Sample Data Versus Corresponding Instantaneous Monitor Data at Glen Ewen, 1978 to 1982.

Date	Temperature (deg C)		Sp. Conductance (us/cm)		pH (pH units)		Dissolved Oxygen (mg/L)	
	Grab	Monitor	Grab	Monitor	Grab	Monitor	Grab	Monitor
6/5/78	21.0	16.4	1313.	1160.	8.4	8.3	10.2	
7/4/78	25.0	24.3	1010.	980.	8.4	8.7	5.4	6.9
8/8/78	21.0		825.	780.	8.0		8.6	
31/10/78	2.5	1.1	1080.	960.	8.0		12.0	4.0
5/12/78	0.5	0.9	1230.	1200.	7.3	7.4	6.7	5.1
15/5/79	10.0	10.2	460.	320.	7.9	8.0	9.5	9.9
12/6/79	20.0	22.2	860.		8.1	8.2	8.0	8.1
14/8/79	16.5	17.1	1250.	980.	8.0	8.4	8.8	8.7
25/9/79	11.0	13.2	1420.	1160.	7.8	8.2	8.0	
23/10/79	2.0	4.6	1600.		7.8	7.5	10.5	
27/11/79	0.0	4.8	1600.	1340.	7.7	7.8	11.6	6.3
10/12/79	0.0	0.0	1800.	1560.	7.7	8.4	10.4	10.2
21/1/80	0.0	0.0	2500.	1920.	7.4	8.2	2.3	1.5
28/5/80	19.0	19.2	1219.	1211.	7.8	8.1	5.7	5.5
25/6/80	18.0	19.5	1650.	1477.	7.9	8.4	6.4	6.2
23/7/80	21.0	20.2	1620.	1586.	8.4	8.5	8.0	5.9
9/9/80	12.5	14.3	1390.	1328.	8.3	8.5	7.1	5.3
15/4/81	6.5	6.7	1066.	1008.	8.1	8.1	12.1	
21/5/81	17.5	17.8	1293.	1164.	8.1	8.1	7.1	6.0
9/6/81	17.0	17.6	1311.	1273.	7.6	7.8	6.9	
14/7/81	22.0	20.9	1342.	1150.	8.2		5.0	
11/8/81	21.6	20.2	1168.	1141.	8.5	8.2	6.0	4.2
21/6/82	20.0	21.0	1069.	1063.	8.0	8.2	8.6	7.5

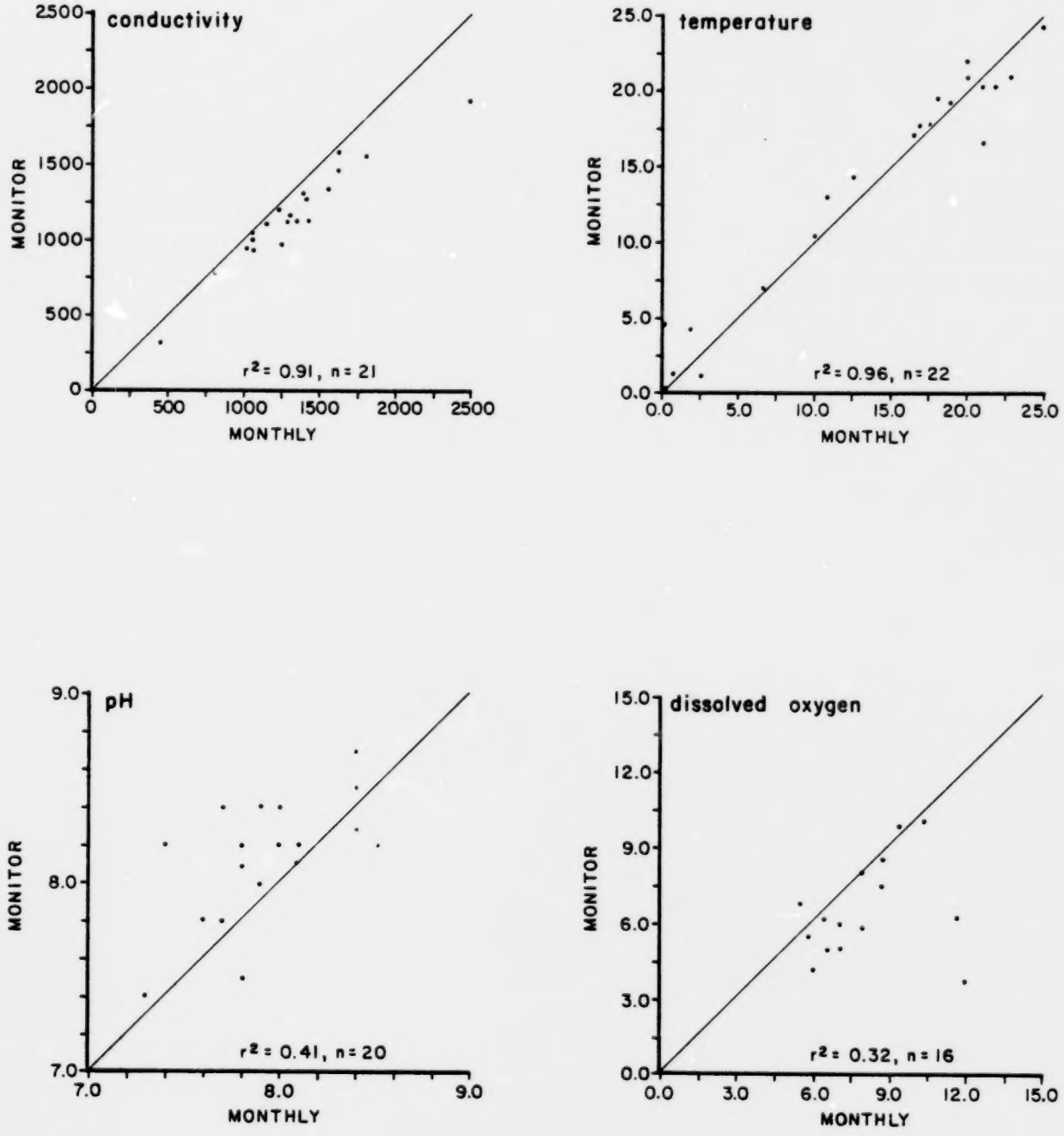

Figure 4. Graphs of Monitor Data versus Monthly Data, Glen Ewen, with the line x = y shown.

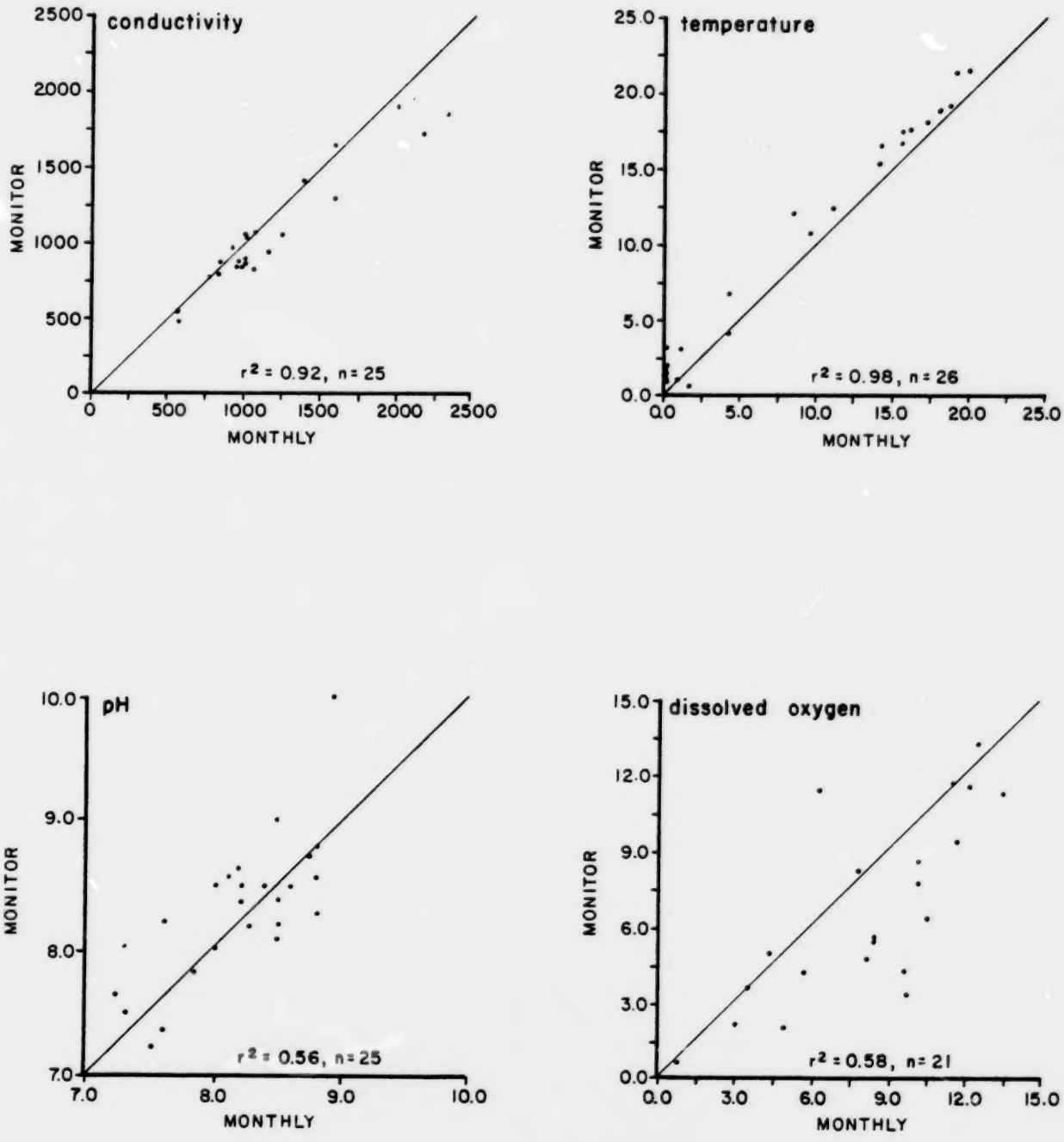

Figure 5. Graphs of Monitor Data versus Monthly Data, Coulter, with the line x = y shown.

of correlation ranging between 0.32 and 0.58.

The poor correlation for pH and dissolved oxygen was apparent during maintenance trips, when the calibration corrections required for these parameters was consistently higher than for temperature and conductivity. There is evidence (Figures 4 and 5) that the probe drift was systematic. Monitor results were generally lower than grab results for dissolved oxygen at both sites, indicating negative drift with time. The pH data from Glen Ewen shows evidence of positive drift. pH error at the Coulter site appears to have been random. This drift in response would have been much less serious had the daily self standardizing facility remained operational throughout the study period, from which corrections could have been applied. Shift corrections were not possible due to the greatly reduced number (average of three per month) of manual calibrations which were performed after self-standardization became inoperable. The lack of accuracy inherent in the pH and dissolved oxygen data largely invalidates the data collected for these parameters as a predictive tool against which any impact of GDUP can be assessed.

3.4 PROGRAM COSTS

An average of three repair trips per month were required for maintenance and repair of the monitors. In some months, as many as six repair trips were necessary. The annual maintenance cost, made up of contractor's salary and expenses, replacement and repair of parts, ranged from approximately $25000 (1978) to $43000 (1981). The initial

capital cost for the monitors was approximately $50000, and for the data transmission equipment, approximately $20000. Cost of installing the monitors, including shelters, air conditioners, power and phone hookups, was in the range of $5000/monitor.

Direct salary costs to the Water Quality Branch were approximately $10000 per year, based on 1981 salaries. This includes the cost of software development, data editing, and coordination of contract personnel.

The total cost of the Glen Ewen and Coulter monitors during the period 1977-1982 was approximately $280000. Over this period, the data record at the two sites consisted of 1509 days with at least 12 hours of record, for an average cost of $185 /site / day of record.

4.0 CONCLUSIONS AND RECOMMENDATIONS

One of the objectives of this program was to provide a sound water quality data base against which some potential effects of the GDUP could be assessed and/or predicted. The use of automatic monitors was not completely effective in acheiving this objective.

The monitors produced results during 50 per cent of the study period. Significant data loss was caused by breakdown of various components of the monitoring system. Murphy's Law was applicable to the operation of these auto-monitors. Operation of the monitors through the winter period was attempted, but monitor shutdowns were often necessary due to freezing problems. This caused the available

data to be weighted toward the open water periods, especially for the Glen Ewen location, where winter shutdown was necessary every year. The data base does not, therefore, describe water quality conditions throughout the year.

Results for conductivity and water temperature were determined to be accurate, when compared with manual measurements, and can be used as an assessment and predictive tool. This was not true for the pH and dissolved oxygen data, which were found to be generally inaccurate. The data for these variables are of insufficient quality to be used extensively with confidence. They may have value in a more limited context, however, to describe annual trends and short-term variability.

The Philips PW9835 monitors were purchased largely on the basis of their self-standardization ability. At that time, there was no alternative monitor available which offered the same features. The cost of these monitors was high, but it was thought that the reduced requirement for manual standardization would more than compensate for the extra initial cost. It soon became obvious, however, that the self-standardization system was inadequately designed for surface waters having high concentrations of suspended materials. In a sense, the Branch pioneered the field use of these monitors, which at the time of purchase, had just entered the market. In hindsight, it may have been preferable to purchase auto-monitors with proven in-field histories, and to accept the necessity of frequent manual standardization-calibration, which could have been performed by local observers. The use of local observers was considered immediately after the self-standardization system became inoperable but attempts to obtain reliable local support were unsuccessful.

The cost of operation of the auto-monitors was extremely high, approximately $280000 over the program duration. The program objective could likely have been met by manual methods at a lower cost. Approximately 3000 samples (observer-collected) for major ions and nutrients could have been collected and analyzed for a similar cost, providing baseline information on a much wider range of variables than can be achieved through auto-monitoring.

Auto-monitors provide information that cannot be collected manually since they are not limited to the constaints of the working day. They can serve a valuable 'watchguard' function in certain situations. However, the collection of data for use in the characterization of water quality conditions throughout the year can probably be more effectively achieved manually than through the use of automated equipment.